The sintering process allows to precisely adjust the required material properties of ceramics, but it also significantly adds to the production costs – good reasons to optimize sintering conditions thoroughly. The thermooptical measuring device »TOMMI« developed at Fraunhofer ISC provides a direct insight into the heat treatment process. While the sample is heated up to 1750°C in the laboratory furnace, a camera detects the shadow cast by the sample, and specific software analyzes the images. Thus, dimensional changes such as sintering shrinkage and warpage can be precisely detected. By using additional equipment deformations under defined load as well as caking, wetting phenomena and weight changes can also be analyzed. »TOMMI« combines the technical features of a dilatometer with those of a heating microscope, a thermogravimetric analyzer (TG) and a thermal mechanical analyzer (TMA). Due to the user-friendly software, »TOMMI« can be applied flexibly for samples and small components of up to a size of 40 mm. »TOMMI« is manufactured in accordance with a certified method, and is successfully applied in ceramic laboratories in Europe, North America and East Asia.

»TOMMI« is one of six subprojects within the Fraunhofer Demonstration Center »AdvanCer« (system solutions with advanced ceramics) that have already been completed.
By thermoplastic vacuum casting ceramic prototypes and small series can be produced fast and cost-efficiently. Thermoplastic vacuum casting is based on the principle of hot molding (low pressure injection molding, LPIM), and uses the good flowability of thermoplastic ceramic suspensions by applying vacuum instead of pressure. If rubber molds are used the so-called soft molding method allows for the casting of contours with undercuts. Both miniaturized and compact prototypes, definitely very complex-shaped ceramic components can be produced. Thermoplastic vacuum casting can also be efficiently used to create and develop new product designs in the field of advanced ceramics as well as household and decorative ceramics.

Process chain for mold manufacturing
In the beginning, a 3D data set is developed from the component to be produced. This data set serves as basis for the manufacturing of a stereolithography model, for example, of which a negative rubber mold is generated. During the designing process of the master pattern and rubber mold, the sintering shrinkage must be considered. If the sintering shrinkage value is not known, it can be determined in advance and also be corrected later by adjusting the geometry of the master pattern in iterative steps.

Mass preparation
By analogy with low pressure injection molding, the thermoplastic suspension (slip) is prepared in a heated ball mill in which a binder mixture of paraffines, waxes and surfactants are melted. The tempered ceramic powder is added in small portions and homogeneously mixed with the binder resulting in a ceramic suspension with high solids content and good flow behavior which is crucial for pressureless vacuum casting. In order to guarantee shape stability of the green bodies during binder removal, a distinct yield point of the slip is advantageous. During slip casting, however, this yield point has to be overcome.

Shape-forming and heat treatment
The thermoplastic ceramic suspension is transferred in a heated casting vessel. This vessel and a preheated rubber mold are placed into a vacuum casting machine. Subsequently, the whole interior is evacuated. Under vacuum the suspension is cast out of the heated vessel into the rubber mold. After filling, the interior is ventilated and the system is cooled down. Afterwards, the component is released from the rubber mold. The following heat treatment process is analogous to the steps in low pressure injection molding. After removing the binder on a porous substrate or in a powder bed, the component is sintered in accordance to the material specifications.

Application of thermoplastic vacuum casting
In contrast to low pressure injection molding, vacuum casting allows for the production of large-volume components, as the hot slip does not solidify prematurely in the heated mold. This method is also interesting for the manufacturing of complex-shaped hollow bodies. For this application a rubber mold is required which in its interior reproduces the outer contour of the desired hollow body. During or after the filling process in which the mold is not completely filled centrifugal forces are applied to the mold until the slip is cooled down and solidified in the interior of the mold. The thickness of the walls that can be obtained depends on the added proportionate amount of slip. Thus, the wall thickness can be limited to dimensions which allow for a defect-free binder removal.

Thermoplastic vacuum casting also provides possibilities for rapid tooling with ceramic tool inserts. A fast supply of tool inserts for plastic injection molding is possible due to the simple process chain. Starting from CAD data of the component, the tool insert is designed and realized as stereolithography model. As material a ceramic is used with high thermal conductivity and a high yield strength. By using silicon infiltrated silicon carbide (SiSiC) one can benefit from the circumstance that SiSiC is virtually unaffected by shrinkage. Thus, scaling becomes unnecessary and warpage of the component during sintering is impossible. The ceramic tool insert has the same dimensions like the master pattern manufactured by stereolithography. The tool insert was just slightly machined at the fitting dimensions and fitted in a cooled master mold.
News
Ceramic experts met in Dresden
The German Ceramic Society (DKG) held this year its annual meeting at Fraunhofer Institute Center in Dresden from March 19 till 20, 2007. As in the previous years, the annual meeting was followed by the symposium »Advanced Ceramics« taking place from March 20 till 21. The fact that Dresden was chosen to host the meeting emphasizes not only Saxony’s importance for the ceramic industry (Meissen is famous worldwide as cradle of the European porcelain), but it also shows that Fraunhofer IKTS is considered as good host and recognized R&D partner. In more than 30 lectures the 150 participants were presented new developments in the field of structural and functional ceramics. The poster session, industry exhibition and guiding tours e.g. through the Porcelain Manufactory of Meissen or the Transparent Factory, supplemented the versatile and interesting conference program. Within the framework of the DKG dinner in historic Factory, supplemented the versatile and pleasant atmosphere.

»AdvanCer« in Hannover
»AdvanCer« once again presents its numerous highlights at this year Hannover Messe taking place from April 16 till 20, 2007. Besides all-ceramic cutters for machining of advanced metal materials, ceramic components with integrated thick-film heating as well as ceramic forming dies for the production of stock pots, »AdvanCer« presents »TOM-AC«, a new development in the field of in-situ measuring methods, which meets the requirement for controlled atmosphere, in Ceramics Meeting Point in hall 5, booth E40. A diesel particulate filter for off-road applications, which was developed by CleanDieselCeramics GmbH in collaboration with Fraunhofer IKTS, is another highlight. Its concept is characterized by innovative filter segments with high filtration areas which show high mechanical strength. Thus, very variable filter geometries can be produced flexibly and cost-efficiently whereby different customers’ requirements can be realized with regard to space and filter size without post processing.

»AdvanCer« is looking forward to your visit. See you in Hannover!

»AdvanCer« at E CerS 2007
For the first time, »AdvanCer« is going to participate at the International Conference and Exhibition of the European Ceramic Society from June 17 till 21, 2007 in Berlin. In addition to diverse lectures, »AdvanCer« presents the research results of Fraunhofer IWM and IKTS within the framework of the industry exhibition.

Diesel particulate filter for off-road applications
(Source: CleanDieselCeramics GmbH)

New demonstration systems for »AdvanCer«
After a successful termination of the first stage of the demonstration center, the participating Fraunhofer Institutes are going to develop five new demonstration systems during the next two years in order to show the properties of advanced ceramics vividly. The planned demonstrators are: »C-SiC« (ceramic bike brake), »TOM-AC« (thermo-optical measurement device with controlled atmosphere), »ToolEx« (wear-resistant ceramic extruder die), »CerGear« (shot-blasted ceramic gear) and »Green-CT« (measurement device for determining densities of green bodies).

Festive colloquium for Cetin Morris Sonsino
As recognition for his 30 years research in the field of structural durability, Fraunhofer LBF held a honorary colloquium for Professor Cetin Morris Sonsino and celebrated his 60th birthday. Numerous scientific prizes and honors, such as the prize of the European Powder Metallurgical Federation, the technology prize of the European Powder Metallurgical Association, Joseph-von-Fraunhofer prize, August Wöhler medal and Skapy prize, reflect his international reputation. His areas of specialty are multiaxiality, elastoplastic material behavior, powder metallurgy as well as advanced ceramics.

Current Training Courses
»AdvanCer« continuous its training courses »Advanced Ceramic Materials for Technicians and Engineers«. Dates and locations are as follows:

- Part 2
  Machining of advanced ceramics. May 8 and 9, 2007 in Aachen
- Part 3
  Construction, quality assurance and application. November 15 and 16, 2006 in Freiburg
  Besides a comprehensive introduction we offer two parallel practical sessions in the field of construction/quality assurance and material testing.

Please find further information under www.advancer.fraunhofer.de

Furthermore, the following advanced training courses of the German Ceramic Society (DKG) will take place at Fraunhofer IKTS in Dresden:

- April 26 and 27, 2007 »Technology fundamentals of granulation and granulate processing« (13th edition)
- September 12 to 14, 2007 »Spray drying of ceramic suspensions – Technology and statistical test planning«
- October 4 and 5, 2007 »Thermoplastic shape-forming of advanced ceramics – Technology and training«

Please find further information under www.dkg.de

Cetin Morris Sonsino, department head »Automotive and Commercial Vehicles« at Fraunhofer LBF and deputy director

Diesel particulate filter for off-road applications
(Source: CleanDieselCeramics GmbH)
Ceramic high voltage insulators

Success Stories

LAPP Insulator GmbH & Co. KG

Dr.-Ing. Bernhard Kahl, managing director of LAPP Insulator GmbH & Co. KG

For more than 100 years the company LAPP Insulator GmbH & Co. KG has been providing high voltage insulators for the transmission and distribution of electricity worldwide. Millions of ceramic insulators and hundred thousands of composite insulators have been in operation for decades – without failure. Thus, LAPP insulator gained confidence from customers worldwide. By optimizing material properties and adapting insulator designs to the particular environmental conditions at site the insulators became one of the most reliable components of energy transmission. There are two different types of insulators: long rod insulators exposed to tensile loading and post insulators subject to compression and bending moments. The product lines of LAPP insulator include both types, both made of technical ceramics as well as composite synthetic materials.

The composite insulators system Rodurflex® consist of two components: a rod made of glass-fiber reinforced epoxy resin and a housing made of silicon elastomer. Ceramic insulators are made of electro-porcelain. Longrod insulators made of technical ceramics can be produced as single unit designs up to a length of 1400 mm, and in special designs up to 1900 mm. Post insulators can be produced as single unit design up to 2600 mm height. In addition to the electrical strength, high mechanical strength is needed requiring an extremely careful manufacturing process consisting of shape-forming, green machining and sintering.

The sintering process of large components can take up to seven days with regard to their size. Thus, it is a cost-intensive and crucial production step. In the framework of a joint project with Fraunhofer ISC the manufacturing of porcelain insulators could be further optimized: On the basis of in-situ measurements during sintering and the resulting FE simulations of stress and temperature fields, the sintering time could be reduced by 40 % at consistent quality.

Aluminum nitride for power electronics

AlN ceramics, in the mid 80’s developed to replace beryllia in microelectronics, have nowadays gained importance in the field of power electronics. AlN ceramics are increasingly used in applications where reliable heat dissipation from semiconductors together with electrical insulation is essential:

- e.g. environmental friendly water cooled inverters and rectifiers in subway trains or, in wind power plants and draglines or partial discharge free highvoltage insulators of converters in express trains, freight-train locomotives or power units of cruise liners.
- In semi-conductor production and in contact with molten metals industry takes advantages of the chemical resistance of AlN under severe process conditions.

For these applications, large ceramic components are produced, considering all well-known problems. In a joint project with Kennametal Hertel GmbH & Co. KG, Ge Metalle und Materialien GmbH and FCT Systeme GmbH, the technological basis for an economical and ecologically safe binder removal and sintering process of large scale components is developed in tight collaboration with Fraunhofer ISC.

AlN evaporation boat for aluminum metal and alloys. Can be used up to approx. 900°C in HCl atmosphere; shown during green machining process.

In the 90’s, Fraunhofer IKTS developed thick-film pastes in the framework of a joint project with ANCeram, and today is one of the most important manufacturer and international supplier of conductor, resistor and encapsulating pastes for thick-film technology on AlN ceramics.

Thus, new and interesting applications can be developed, e.g. in optical and diode laser applications based on ANCeram’s aluminum nitride.